3.2.1 Dynamics

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	net force = mass × acceleration; $F = ma$	Learners will also be expected to recall this equation. *M1.1*
(b)	the newton as the unit of force	
(c)	weight of an object; $W = mg$	Learners will also be expected to recall this equation.
(d)	the terms tension, normal contact force, upthrust and friction	
(e)	free-body diagrams	
(f)	one- and two-dimensional motion under constant force.	

3.2.2 Motion with non-uniform acceleration

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	drag as the frictional force experienced by an object travelling through a fluid	
(b)	factors affecting drag for an object travelling through air	HSW6
(c)	motion of objects falling in a uniform gravitational field in the presence of drag	HSW9
(d) **(i)**	terminal velocity	HSW1, 5
(ii)	techniques and procedures used to determine terminal velocity in fluids.	**PAG1** e.g. ball-bearing in a viscous liquid or cones in air. HSW4 Investigating factors affecting terminal velocity

3.2.3 Equilibrium

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	moment of force	
(b)	couple; torque of a couple	
(c)	the principle of moments	
(d)	centre of mass; centre of gravity; experimental determination of centre of gravity	
(e)	equilibrium of an object under the action of forces and torques	
(f)	condition for equilibrium of three coplanar forces; triangle of forces.	*M4.1, M4.2, M4.4*

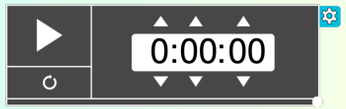
3.2.4 Density and pressure

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	density; $\rho = \frac{m}{V}$	*M0.1, M4.3*
(b)	pressure; $p = \frac{F}{A}$ for solids, liquids and gases	
(c)	$p = h\rho g$; upthrust on an object in a fluid; Archimedes' principle.	*M2.1* HSW4, 7, 11

(6) M - Recall basic forces and draw free body force diagrams
(7) S - Recall and apply the equation for resultant force
(8) C - Find the acceleration of an object acted on by more than one force.

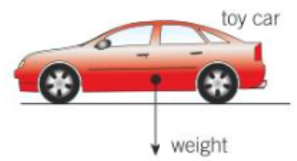
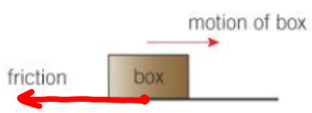
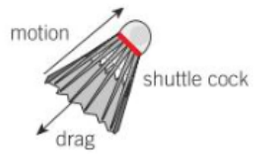
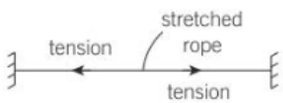
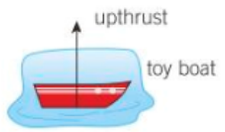
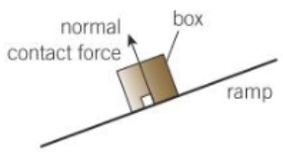
Forces and mass

STARTER: How many forces can you name?



Extension: What is a force? what can its do? How do we represent them?

▼ **Table 1** *A summary of key forces*

Force	Comment	Force diagram
weight	the gravitational force acting on an object through its centre of mass	
friction	the force that arises when two surfaces rub against each other	
drag	the resistive force on an object travelling through a fluid (e.g., air and water); the same as friction	
tension	the force within a stretched cable or rope	
upthrust	an upward buoyancy force acting on an object when it is in a fluid	
normal contact force	a force arising when one object rests against another object	

Perpendicular to the surface

(6) M - Recall basic forces and draw free body force diagrams
(7) S - Recall and apply the equation for resultant force
(8) C - Find the acceleration of an object acted on by more than one force.

Drawing a free body force diagram

- Each force vector is represented by an arrow labelled with the force it represents and the magnitude
- Each arrow is drawn to the same scale (length proportional to magnitude)
- Best practice: arrows originate form the centre of mass or point of application

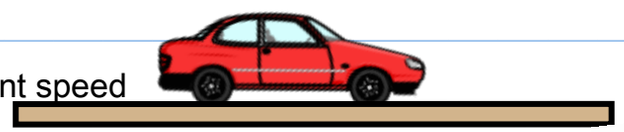
Activity: Sketch and label 3 the free body force diagram of the following.

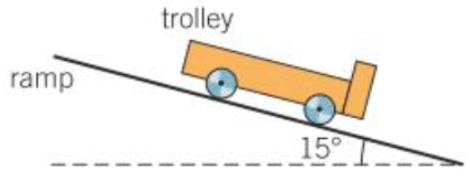
Forces

Label the forces acting on:

- Person standing still
- A box on the floor
- A ball floating still
- A swimmer at constant speed
- A car accelerating
- A plane taking off a runway
- Trolly accelerating down a ra

components)





(6) M - Recall basic forces and draw free body force diagrams
(7) S - Recall and apply the equation for resultant force
(8) C - Find the acceleration of an object acted on by more than one force.

Force and mass

0:02:52

Starter

Compare and contrast mass and weight.

Add to your map after the video. Consider,

definitions, basic equations that relate them, units.

▲ **Figure 1** *One of the UK's three standard kilograms, a 39.17 mm high cylinder of platinum–iridium alloy stored in a bell jar at the National Physical Laboratory*

Mass

Weight

the grand k

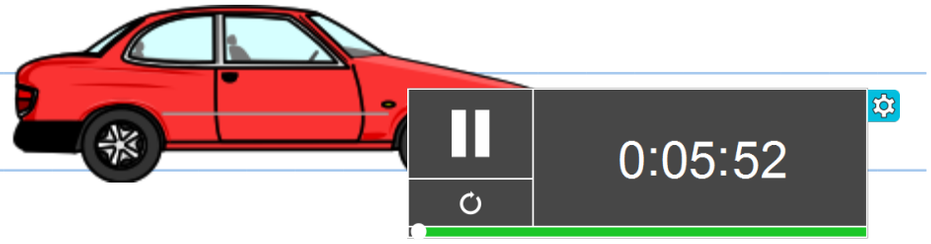
Ex: How could you change your weight without changing your mass?

How could you change your mass without changing the number of particles that make up your body?

(6) M - Recall basic forces and draw free body force diagrams
(7) S - Recall and apply the equation for resultant force
(8) C - Find the acceleration of an object acted on by more than one force.

Forces and mass

This car is accelerating.



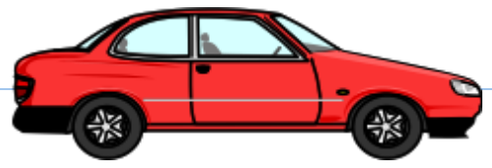
The car has a mass of 2.1×10^3 kg. It accelerates from rest to 27 ms^{-1} in 5.4s. The frictional force is 800N

S
A

1. Sketch a free body force diagram of the car
2. Calculate the average net force acting on the car
3. What is the thrust to weight ratio of the car?

Ex:if at 5.4s it flew off a cliff. What would be the velocity at 6 seconds?

1



2 Find the acceleration using the equations of motion.

Use F=ma

3 Find the thrust using vector addition.

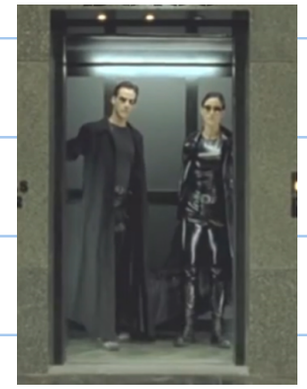
Find weight from W = mg

(6) M - Recall basic forces and draw free body force diagrams
(7) S - Recall and apply the equation for resultant force
(8) C - Find the acceleration of an object acted on by more than one force.

Elevator example problem

A 75kg man stands on a balance in an elevator. When the elevator begins to rise, the balance reads 100kg.

What is the acceleration of the person?



S
A

Answer

The balance is the reading of the normal contact force.

$N_{UP} = mg + ma = 100\ kg$

$N_{REST} = mg = 75\ kg$

(6) M - Recall basic forces and draw free body force diagrams
(7) S - Recall and apply the equation for resultant force
(8) C - Find the acceleration of an object acted on by more than one force.

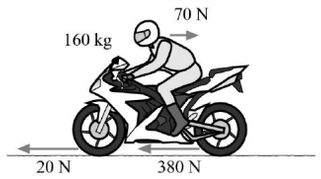
Forces and mass

Activity: Complete the worksheet questions.

Ex: Start from higher level.

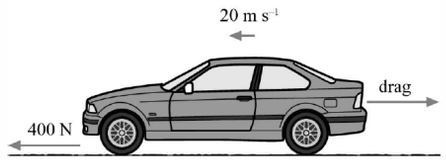
Higher level

7 The diagram shows the horizontal forces acting on a motorbike and its rider travelling along a level road. The total mass of the rider and the motorbike is 160 kg. Determine the acceleration of the motorbike. [3]



Extension

9 The diagram shows the horizontal forces acting on a 920 kg car.

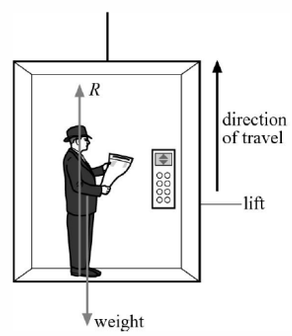


The total forward force acting on the car is 400 N. The drag on the car depends on its speed v and is given by the expression:

$$\text{drag} = 0.3v^2$$

a At a particular instant the car is travelling at a speed of 20 m s^{-1}. Calculate:
i the net force on the car [2]
ii the acceleration of the car. [2]
b Explain why you cannot use
$$v = u + at$$
to determine the velocity of the car after a time t. [1]

10 The diagram shows an 80 kg person in a lift.



The normal contact force acting on the person from the base of the lift is R. Determine the magnitude of R when the lift:

a is travelling upwards at a constant velocity of 2.0 m s^{-1} [2]
b is accelerated upwards at 2.3 m s^{-2}. [3]

(6) M - Recall basic forces and draw free body force diagrams
(7) S - Recall and apply the equation for resultant force
(8) C - Find the acceleration of an object acted on by more than one force.

Mini plenary

A rocket of mass 12 000 kg accelerates vertically upwards from the surface of the Earth at 1.4 m s^{-2}.

What is the thrust of the rocket?

$F = T - W$
$T = F + W$

F ↑ T

$F = ma$
$= 12000 \times 1.4$
$= 16800\ N$

$W = mg = 12000\ g$

A 1.7×10^4 N ⬭

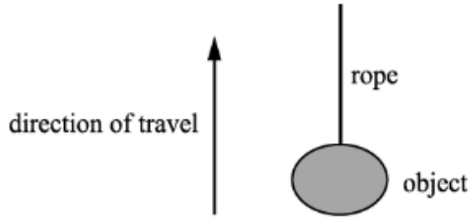
B 1.7×10^5 N ⬭

C 1.3×10^5 N ⬭ C

D 1.6×10^5 N ⬭

Mini plenary

An object of mass 7.0 kg is pulled vertically upwards by a rope. The acceleration of the object is 2.0 m s^{-2}.



What is the tension in the rope?

A. 14 N

B. 55 N

C. 69 N

D. 83 N